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**Battelle Commentary on the Elementa Technology**

Battelle's founding mission as an independent, non-profit science and technology institute is to bring new technologies and solutions into the commercial marketplace for the betterment of society. We do this by bringing deep, multidisciplinary expertise into the development and commercialization of both our own ideas and the ideas of others. We carefully select technologies to focus on based on their technical merit, our capability to effectively assist in development, and the market opportunity, or need.

The Elementa process for steam reforming of solid waste and biomass fits well with Battelle's mission and capability set. We have been working in gasification of coal, biomass, and other materials since the early 1980s and were the first to commercialize a wood gasification technology in North America in the 1990s. We are currently developing our own catalytic pyrolysis process for the conversion of woody biomass to bio-products and transportation fuel. While Elementa has focused on the conversion of municipal solid waste to electricity as a first commercial outcome, the data that they have collected from five years of pilot operation suggest that there are many potential market applications for the technology, including the conversion of solid waste and other carbonaceous feed stocks to fuel or bio-products.

From a technical standpoint, Elementa's steam reforming process is fundamentally different from competing waste-to-energy technologies. It provides for a reaction of steam with the carbonaceous feed that produces a clean, high-quality synthesis gas with a high heating value, allowing the process to be coupled with the most efficient power-generation technologies (i.e. combined-cycle gas turbines). The product synthesis gas also has an abnormally high ratio of hydrogen to carbon monoxide, making it a candidate for direct conversion to transportation fuel via Fischer Tropsch processing. Because no air or oxygen are introduced in the process, as they are in incineration and gasification, the Elementa process produces no toxic emissions (dioxin, furan, noxious oxides). Because it operates at relatively high temperature (> 850C), it produces little of the char and tar that pyrolysis generates, allowing more conversion of feed to useful synthesis gas and enabling recovery of energy from the raw gas without excessive maintenance complexity and cost. The raw gas can be cooled in the heat-recovery process, reducing the temperature, volume, complexity, and cost of gas cleanup. Compared to competing technologies, the Elementa process has been demonstrated through pilot operation to have nearly twice the overall efficiency with lower capital and operating costs, and with no toxic emissions.

This assessment is being provided for informational purposes to outline the reasons for Battelle's interest in assisting Elementa with further development and commercialization of their steam reforming process. It aligns well with our strategic interests and capabilities in the clean energy space, there are still opportunities to improve the technology based on our experience, and there are multiple near-term commercial applications for the technology. We are in the process of formalizing our long term relationship with Elementa, which will include providing fee-based technical support for the commercial project in Sault Ste Marie. We will also establish a joint development agreement and commit internal resources to assist with development and commercialization of the technology for applications beyond electricity.

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